An Efficient Implementation of a Local Binning Algorithm for Digital Elevation Model Generation of LiDAR/ALSM Datasets

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The GEON LiDAR Workflow (GLW) project (http://www.geongrid.org/science/lidar.html) has enabled geoscientific communities to process and download large LiDAR (Light Distance And Ranging), or ALSM (Airborne Laser Swath Mapping) datasets. The products--digital elevation models (DEMs)--are essential representations of the landscape that are imported to various off-the-shelf geoscientific tools. Initially, the GLW utilized the regularized spline with tension interpolation algorithm for the DEM generation from GRASS GIS successfully for small datasets (<1.6 million points). However, it is compute-intensive; in order to process 5 million points, it takes about 50 minutes on the Linux machine in a GEON cluster. As a solution to the problem, a local binning algorithm which quickly generates a DEM is employed. The algorithm utilizes the elevation information from only the points inside of a circular search area with user specified radius (Figure 1). For each node in a grid, five values are computed: the minimum, maximum, mean, and inverse distance weighted mean of the local points, and the number of points in the search area. The noble implementation technique can produce a grid containing those five values within O(N) time, where N denotes the size of the LiDAR point cloud. This implementation runs over 5 million points in 30 seconds in a single machine, which is about 100 times speedup relative to the $O(N^2)$ spline or related methods. Along with the original implementation, an out-of-core (memory) version of the local binning algorithm has also been developed. This implementation exploits secondary storage for saving intermediate results when the size of a grid exceeds that of memory. The large grid is split into several small pieces. During the computation, each piece is fetched from secondary storage to main memory one at a time when needed. This version can compute a DEM from 150 million points (in about 20 minutes), which is impossible in the spline interpolation and also in the original local binning algorithm implementation. In addition, the local binning algorithm computes useful products. The maximum values track the highest elevation points, which are usually recorded at the top of vegetation areas. On the other hand, the minimum values may represent the information bounced from the ground, which is useful for meter-scale shrubbery removal for which there will not usually be laser penetration. Lastly, the density map of an area is useful when determining the accuracy of interpolation and assessing the appropriate grid resolution (Figure 2). This suite of DEM products provides geoscientists rich information complementary to those of the current spline algorithm. We have also ported this code to Windows (GEON Points2Grid Utility).

Links:

http://lidar.asu.edu/points2grid.html (GEON Points2Grid Utility page);
http://lidar.asu.edu/knowledgebase.html (prototype and supporting documentation);
http://lidar.asu.edu/ (ASU LiDAR research).

Reference:

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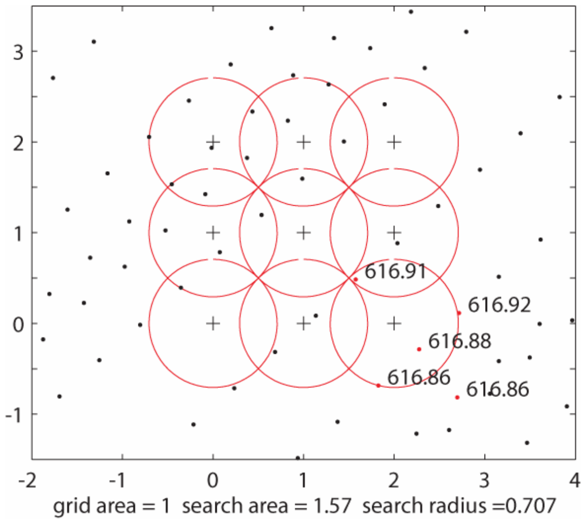

Figure 1. Illustration of local binning geometry (map view). Black dots are actual LiDAR shots from B4 San Andreas Laser Scan project in the Carrizo Plain, California. Red ones in lower right have elevations shown. Plus symbols indicate locations of DEM nodes at which elevation is estimated (minimum, maximum, mean, or inverse distance-weighted mean) based on points within search radius (shown as red circle). In this case. The search radius is equal to the grid resolution * sqrt(2) / 2. The grid scale is in meters.

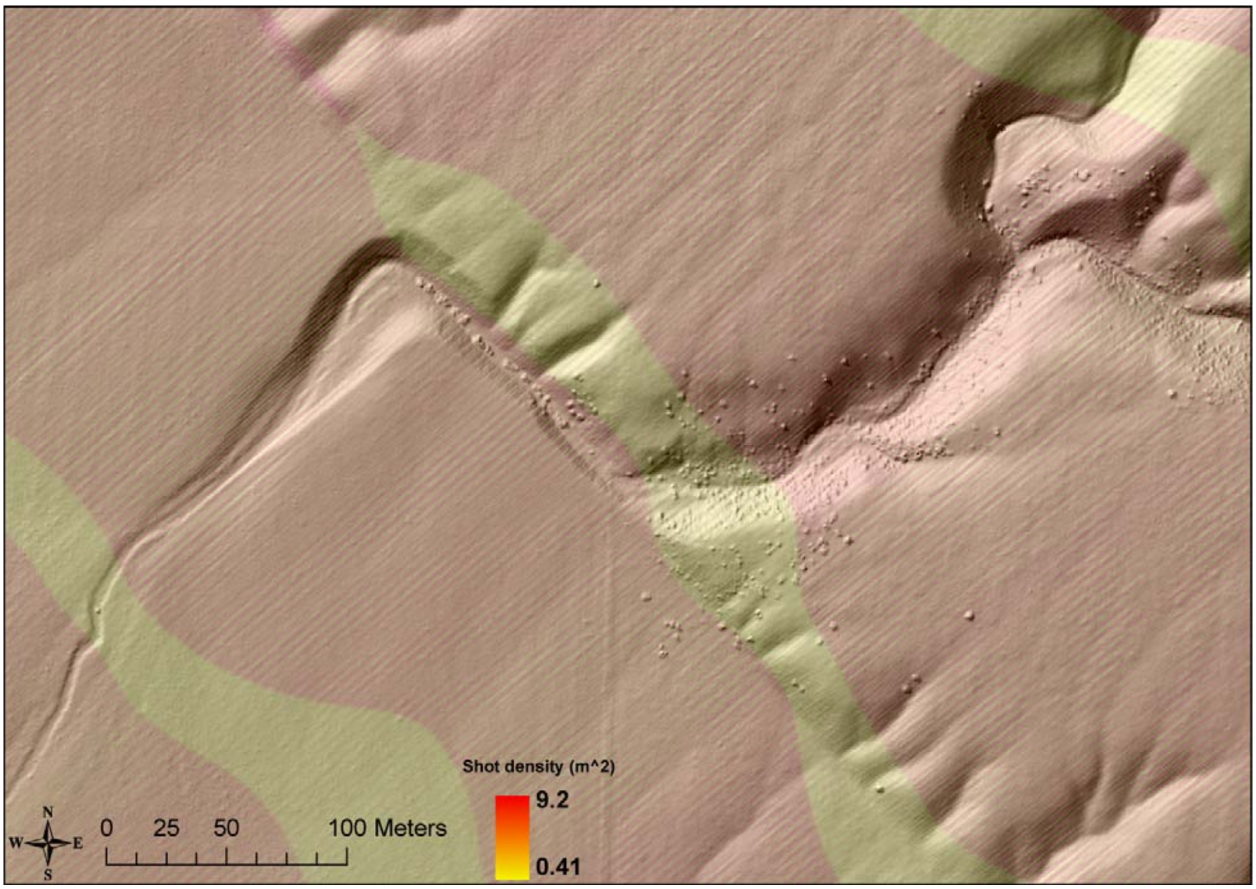

Figure 2. Wallace Creek area along the San Andreas Fault in south central California depicted in a 0.5 m DEM computed using our local binning algorithm (1.25 m search radius). The shot density overlay illustrates the strong heterogeneity of LiDAR ground returns. Low densities are in areas of single swaths, while the high densities come from multiple swaths. Easy computation of the DEM and density enable scientists to not only study this spectacular tectonic geomorphology, but also to appreciate the quality of the underlying representation.